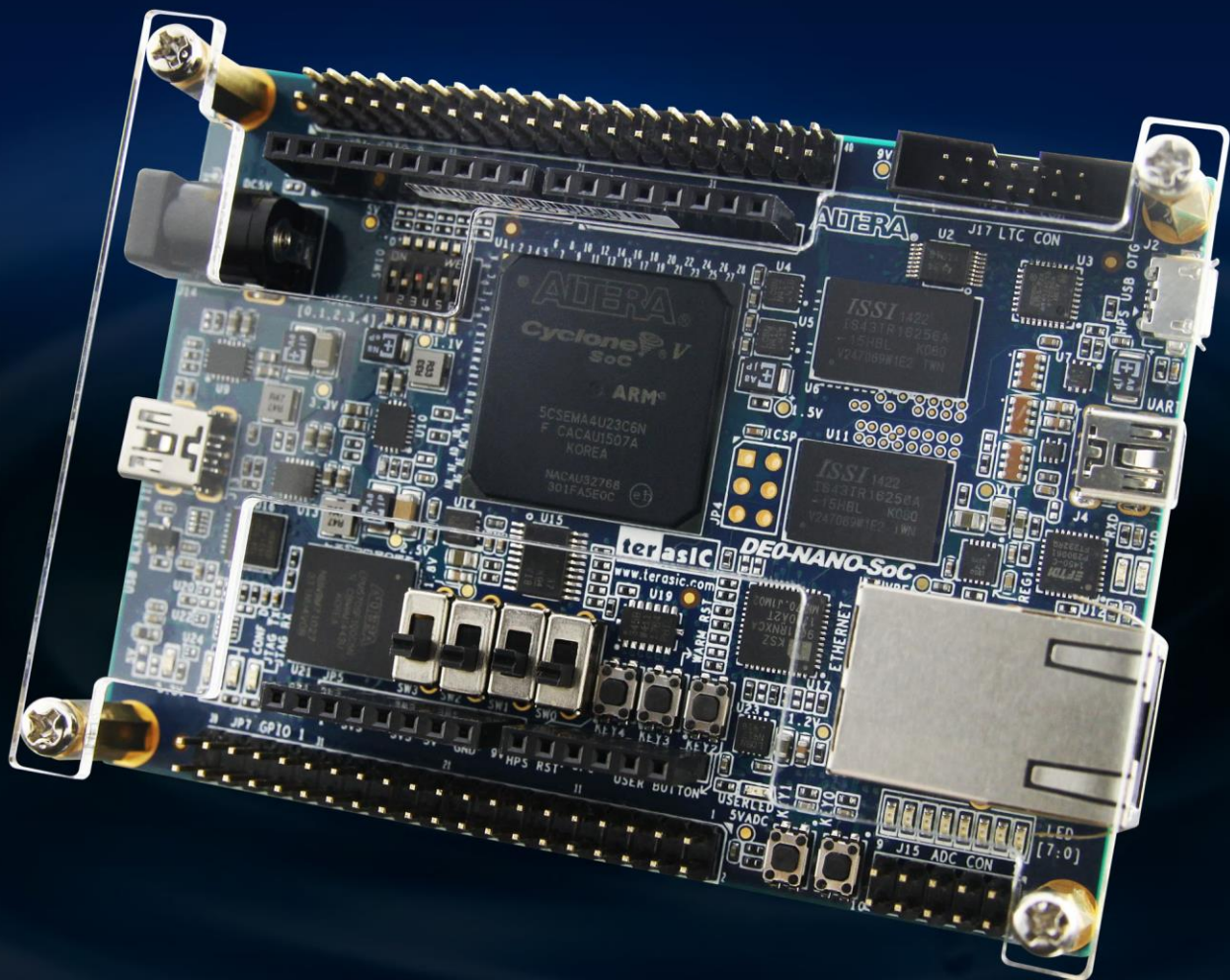




Atlas-SoC kit

USER MANUAL



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Chapter 1

Atlas-SoC Software Development Kit

The Atlas-SoC Software Development Kit presents a robust hardware design platform built around the Altera System-on-Chip (SoC) FPGA, which combines the latest dual-core Cortex-A9 embedded cores with industry-leading programmable logic for ultimate design flexibility. Users can now leverage the power of tremendous re-configurability paired with a high-performance, low-power processor system. Altera's SoC integrates an ARM-based hard processor system (HPS) consisting of processor, peripherals and memory interfaces tied seamlessly with the FPGA fabric using a high-bandwidth interconnect backbone. The Atlas-SoC development board is equipped with high-speed DDR3 memory, analog to digital capabilities, Ethernet networking, and much more that promise many exciting applications.

The Atlas-SoC Software Development Kit contains all the tools needed to use the board in conjunction with a computer that runs the Microsoft Windows XP or later.

1.1 Package Contents

Figure 1-1 shows a photograph of the Atlas-SoC package.



Figure 1-1 The Atlas-SoC package contents

The Atlas-SoC package includes:

- The Atlas-SoC development board
- Atlas-SoC Quick Start Guide
- USB cable (Type A to Mini-B) for FPGA programming and control
- USB cable (Type A to Mini-B) for UART control
- 5V/2A DC power adapter
- 4GB microSD Card (Installed)

1.2 Atlas-SoC System CD

The Atlas-SoC System CD contains all the documents and supporting materials associated with Atlas-SoC, including the user manual, system builder, reference designs, and device datasheets. Users can download this system CD from the link: <http://soc.terasic.com>.

1.3 Getting Help

Here are the addresses where you can get help if you encounter any problems:

Community Support

<http://www.rocketboards.org/atlas-soc>

Terasic Technologies

9F., No.176, Sec.2, Gongdao 5th Rd, East Dist, Hsinchu City, 30070. Taiwan

Email: support@terasic.com

Tel.: +886-3-575-0880

Website: Atlas-SoC.terasic.com

Chapter 2

Introduction of the Atlas-SoC Board

This chapter provides an introduction to the features and design characteristics of the board.

2.1 Layout and Components

Figure 2-1 and Figure 2-2 shows a photograph of the board. It depicts the layout of the board and indicates the location of the connectors and key components.

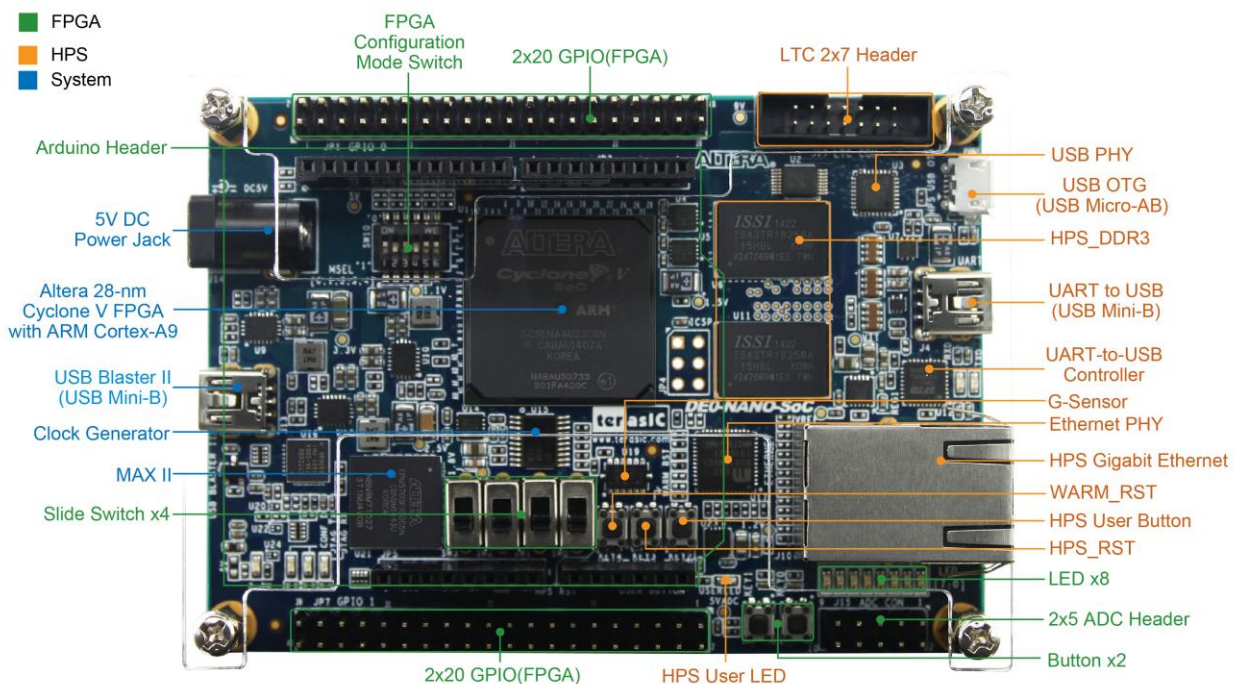


Figure 2-1 Atlas-SoC development board (top view)

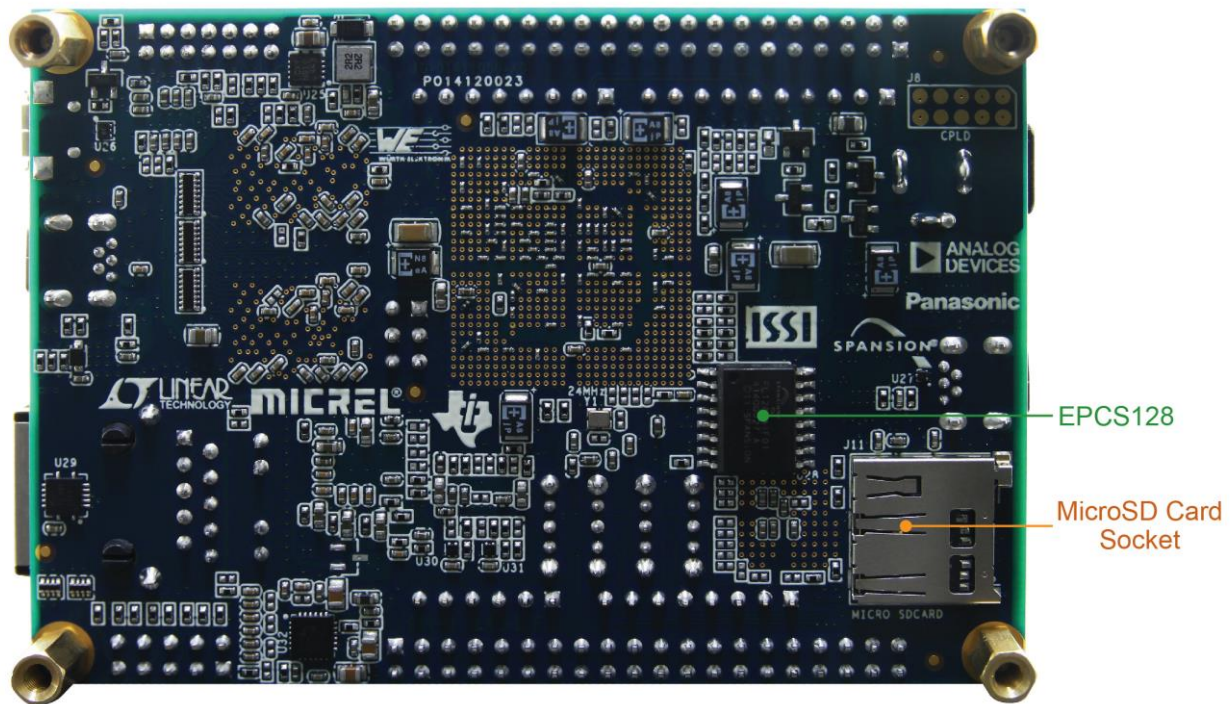


Figure 2-2 Atlas-SoC development board (bottom view)

The Atlas-SoC board has many features that allow users to implement a wide range of designed circuits, from simple circuits to various multimedia projects.

The following hardware is provided on the board:

■ FPGA

- Altera Cyclone® V SE 5CSEMA4U23C6N device
- Serial configuration device – EPCS128
- USB-Blaster II onboard for programming; JTAG Mode
- 2 push-buttons
- 4 slide switches
- 8 green user LEDs
- Three 50MHz clock sources from the clock generator
- Two 40-pin expansion header
- One Arduino expansion header (Uno R3 compatibility), can connect with Arduino shields.
- One 10-pin Analog input expansion header. (shared with Arduino Analog input)
- A/D converter, 4-wire SPI interface with FPGA

■ HPS (Hard Processor System)

- 925MHz Dual-core ARM Cortex-A9 processor
- 1GB DDR3 SDRAM (32-bit data bus)
- 1 Gigabit Ethernet PHY with RJ45 connector
- port USB OTG, USB Micro-AB connector
- Micro SD card socket
- Accelerometer (I2C interface + interrupt)
- UART to USB, USB Mini-B connector
- Warm reset button and cold reset button
- One user button and one user LED
- LTC 2x7 expansion header

2.2 Block Diagram of the Atlas-SoC Board

Figure 2-3 is the block diagram of the board. All the connections are established through the Cyclone V SoC FPGA device to provide maximum flexibility for users. Users can configure the FPGA to implement any system design.

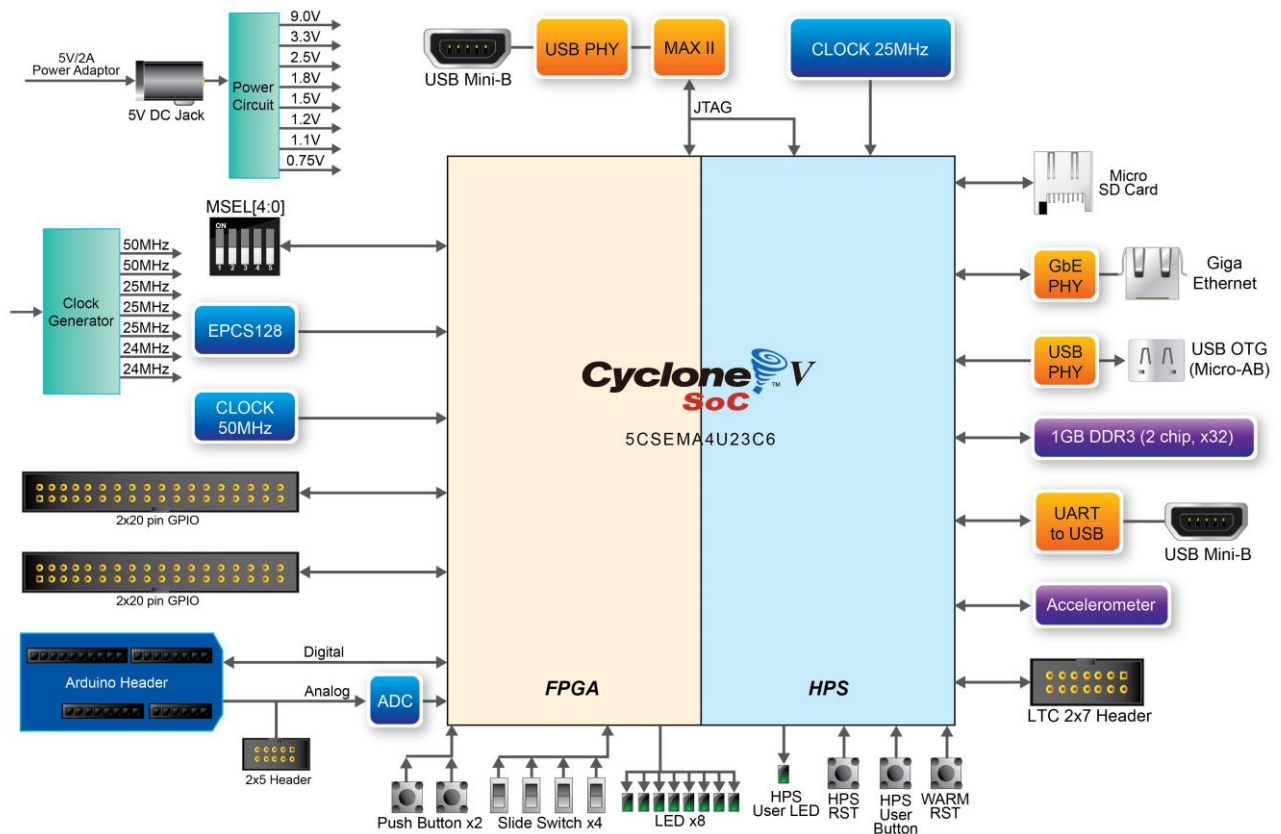


Figure 2-3 Block diagram of Atlas-SoC

Detailed information about **Figure 2-3** are listed below.

FPGA Device

- Cyclone V SoC 5CSEMA4U23C6N Device
- Dual-core ARM Cortex-A9 (HPS)
- 40K programmable logic elements
- 2,460 Kbits embedded memory
- 5 fractional PLLs
- 2 hard memory controllers

Configuration and Debug

- Serial configuration device – EPCS128 on FPGA
- Onboard USB-Blaster II (Mini-B USB connector)

Memory Device

- 1GB (2x256Mx16) DDR3 SDRAM on HPS
- Micro SD card socket on HPS

Communication

- One USB 2.0 OTG (ULPI interface with USB Micro-AB connector)
- UART to USB (USB Mini-B connector)
- 10/100/1000 Ethernet

Connectors

- Two 40-pin expansion headers
- Arduino expansion header
- One 10-pin ADC input header
- One LTC connector (one Serial Peripheral Interface (SPI) Master ,one I2C and one GPIO interface)

ADC

- 12-Bit Resolution, 500Ksps Sampling Rate. SPI Interface.
- 8-Channel Analog Input. Input Range : 0V ~ 4.096V.

Switches, Buttons, and Indicators

- 3 user Keys (FPGA x2, HPS x1)
- 4 user switches (FPGA x4)
- 9 user LEDs (FPGA x8, HPS x 1)
- 2 HPS reset buttons (HPS_RESET_n and HPS_WARM_RST_n)

Sensors

- G-Sensor on HPS

Power

- 5V DC input

Chapter 3

Using the Atlas-SoC Board

This chapter provides an instruction to use the board and describes the peripherals.

3.1 Settings of FPGA Configuration Mode

When the Atlas-SoC board is powered on, the FPGA can be configured from the SD Card (default), but it can also be configured by the EPCS flash device as well. The MSEL[4:0] pins are used to select the configuration scheme. It is implemented as a 6-pin DIP switch **SW10** on the Atlas-SoC board, as shown in **Figure 3-1**.

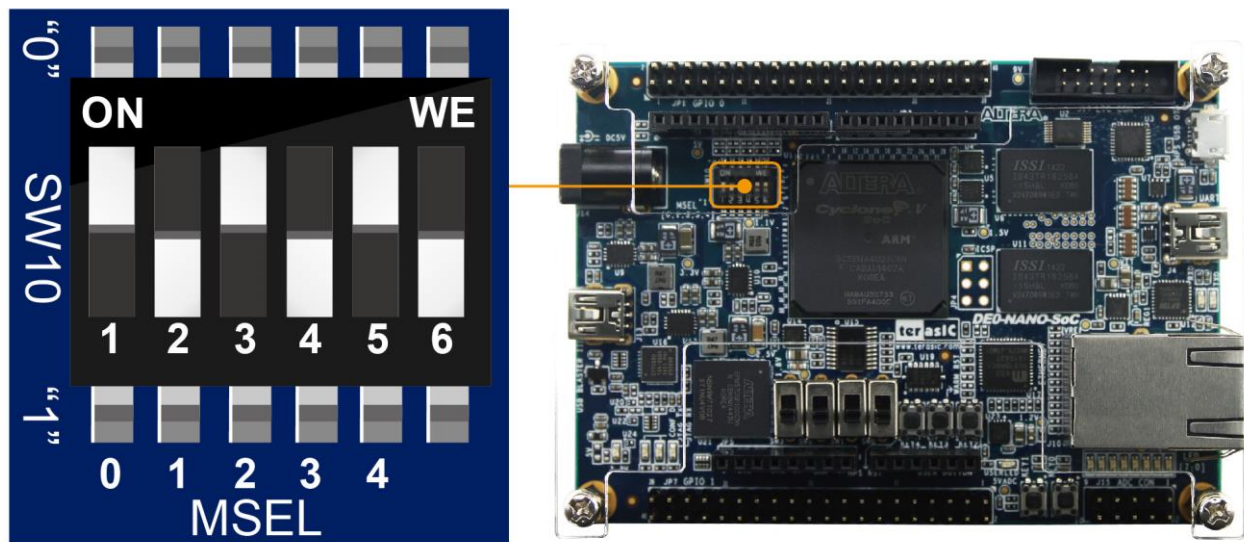


Figure 3-1 DIP switch (SW10) setting of FPP x32 mode

Table 3-1 shows the relation between MSEL[4:0] and DIP switch (SW10).

Table 3-1 FPGA Configuration Mode Switch (SW10)

<i>Board Reference</i>	<i>Signal Name</i>	<i>Description</i>	<i>Default</i>
SW10.1	MSEL0	Use these pins to set the FPGA Configuration scheme	ON ("0")
SW10.2	MSEL1		OFF ("1")
SW10.3	MSEL2		ON ("0")
SW10.4	MSEL3		OFF ("1")
SW10.5	MSEL4		ON ("0")
SW10.6	N/A	N/A	N/A

Table 3-2 shows MSEL[4:0] setting for FPGA configure, and default setting is FPPx32 mode on Atlas-SoC.

When the board is powered on and MSEL[4:0] set to "10010", the FPGA is configured from EPCS, which is pre-programmed with the default code. If developers wish to configure FPGA from an application software running on Linux, the MSEL[4:0] needs to be set to "01010" before the programming process begins. If developers using the "Linux Console with frame buffer" or "Linux LXDE Desktop" SD Card image, the MSEL[4:0] needs to be set to "00000" before the board is powered on.

Table 3-2 MSEL Pin Settings for FPGA Configure of Atlas-SoC

<i>Configuration</i>	<i>SW10.1 MSEL0</i>	<i>SW10.2 MSEL1</i>	<i>SW10.3 MSEL2</i>	<i>SW10.4 MSEL3</i>	<i>SW10.5 MSEL4</i>	<i>SW10.6</i>	<i>Description</i>
AS	ON	OFF	ON	ON	OFF	N/A	FPGA configured from EPCS
FPPx32 (Default)	ON	OFF	ON	OFF	ON	N/A	FPGA configured from HPS software: Linux (default)
FPPx16	ON	ON	ON	ON	ON	N/A	FPGA configured from HPS software: U-Boot, with image stored on the SD card, like LXDE Desktop or console Linux with frame buffer edition.

3.2 Board Status Elements

In addition to the 9 LEDs that FPGA/HPS device can control, there are 6 indicators which can indicate the board status (See [Figure 3-2](#)), please refer the details in [Table 3-3](#)

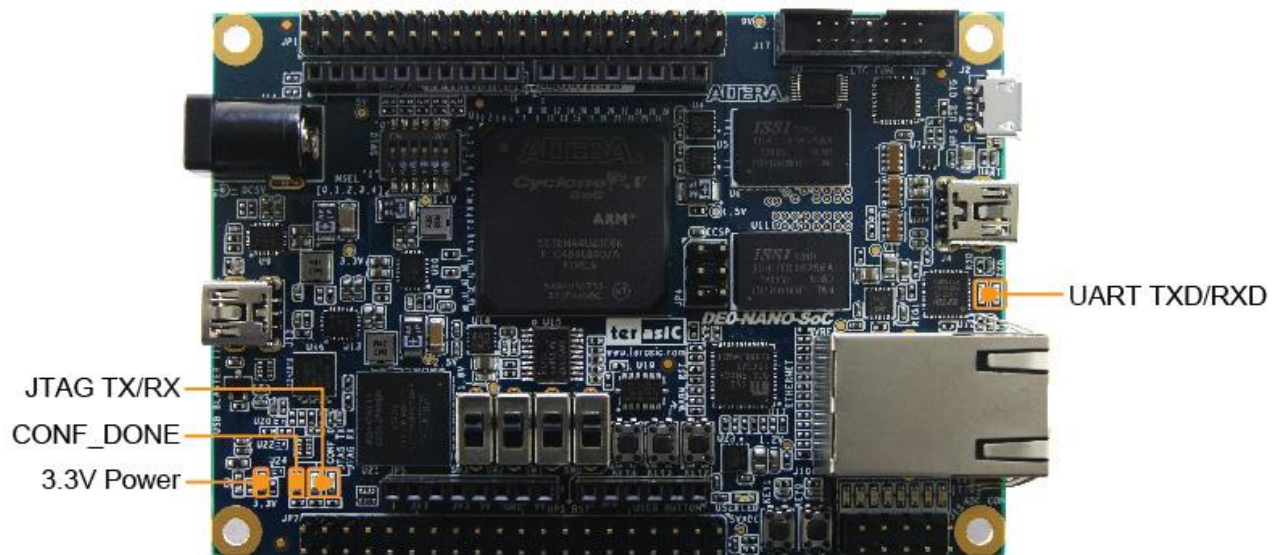


Figure 3-2 LED Indicators on Atlas-SoC

Table 3-3 LED Indicators

Board Reference	LED Name	Description
LED9	3.3-V Power	Illuminate when 3.3V power is active.
LED10	CONF_DONE	Illuminates when the FPGA is successfully configured.
LED11	JTAG_TX	Illuminate when data is transferred from JTAG to USB Host.
LED12	JTAG_RX	Illuminate when data is transferred from USB Host to JTAG.
TXD	UART TXD	Illuminate when data is transferred from FT232R to USB Host.
RXD	UART RXD	Illuminate when data is transferred from USB Host to FT232R.

3.3 Board Reset Elements

There are two HPS reset buttons on Atlas-SoC, HPS (cold) reset and HPS warm reset, as shown in **Figure 3-3**. **Table 3-4** describes the purpose of these two HPS reset buttons. **Figure 3-4** is the reset tree for Atlas-SoC.

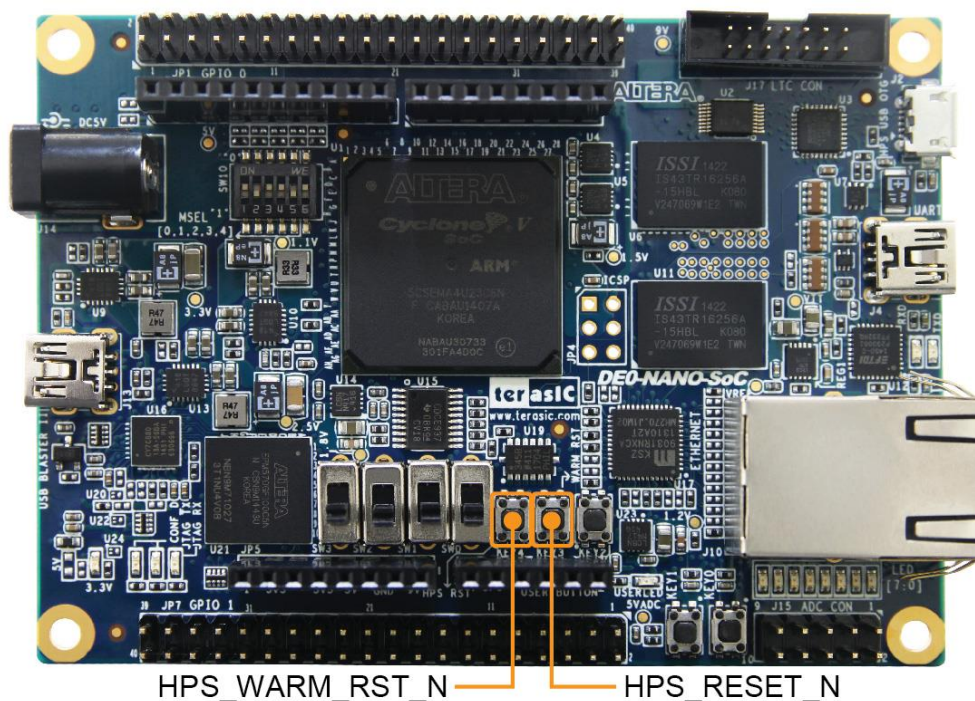


Figure 3-3 HPS cold reset and warm reset buttons on Atlas-SoC

Table 3-4 Description of Two HPS Reset Buttons on Atlas-SoC

Board Reference	Signal Name	Description
KEY4	HPS_RESET_N	Cold reset to the HPS, Ethernet PHY and USB host device. Active low input which resets all HPS logics that can be reset.
KEY3	HPS_WARM_RST_N	Warm reset to the HPS block. Active low input affects the system reset domain for debug purpose.

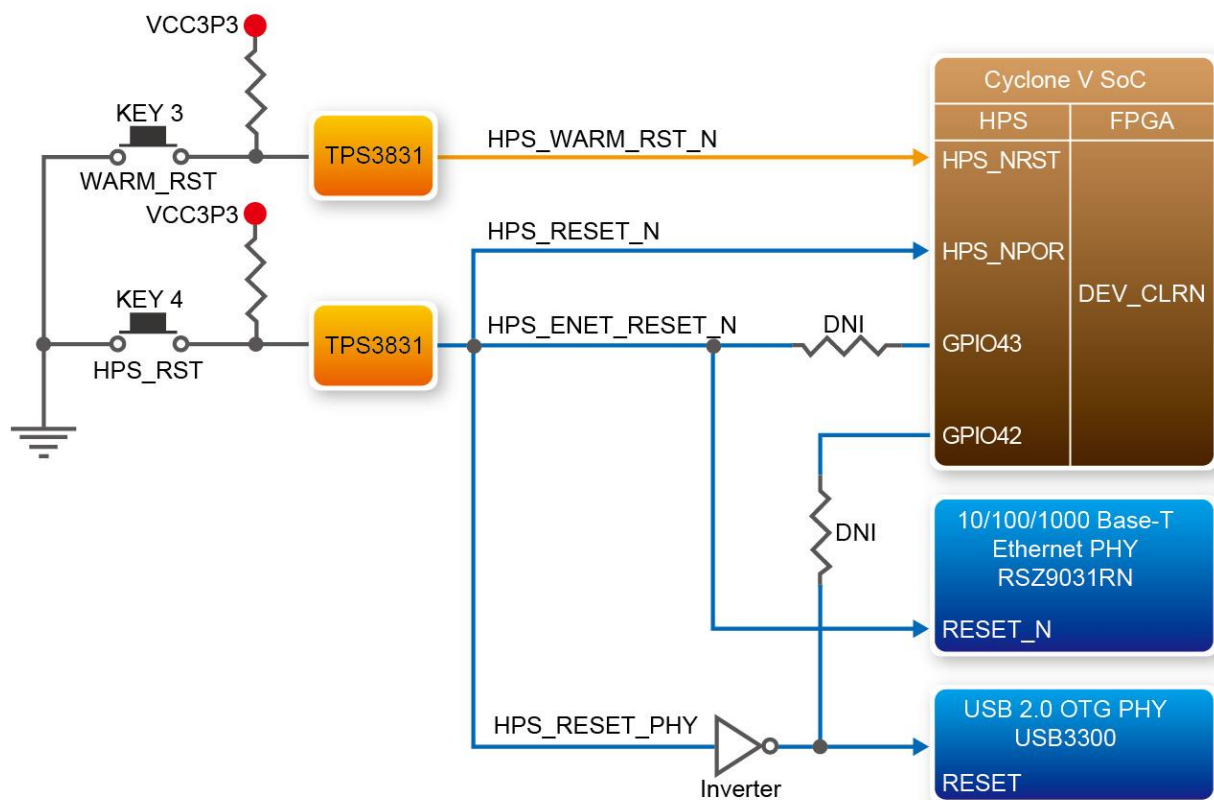


Figure 3-4 HPS reset tree on Atlas-SoC board

3.4 Clock Circuitry

Figure 3-5 shows the default frequency of all external clocks to the Cyclone V SoC FPGA. A clock generator is used to distribute clock signals with low jitter. The two 50MHz clock signals connected to the FPGA are used as clock sources for user logic. Three 25MHz clock signal are connected to two HPS clock inputs, and the other one is connected to the clock input of Gigabit Ethernet Transceiver. One 24MHz clock signal is connected to the USB controller for USB Blaster II circuit and FPGA. One 24MHz clock signals are connected to the clock inputs of USB OTG PHY. The associated pin assignment for clock inputs to FPGA I/O pins is listed in Table 3-5.

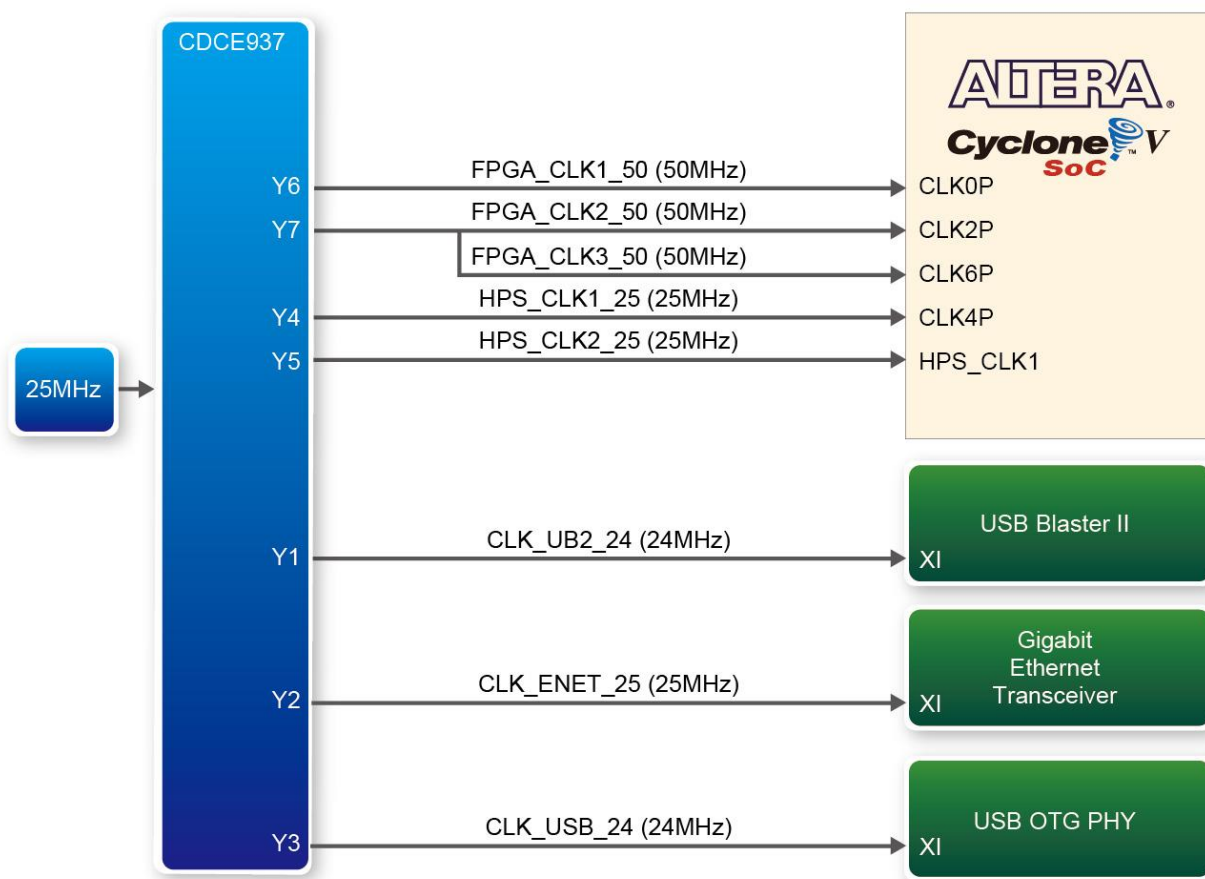


Figure 3-5 Block diagram of the clock distribution on Atlas-SoC

Table 3-5 Pin Assignment of Clock Inputs

Signal Name	FPGA Pin No.	Description	I/O Standard
FPGA_CLK1_50	PIN_V11	50 MHz clock input	3.3V
FPGA_CLK2_50	PIN_Y13	50 MHz clock input	3.3V
FPGA_CLK3_50	PIN_E11	50 MHz clock input (share with FPGA_CLK1_50)	3.3V
HPS_CLK1_25	PIN_E20	25 MHz clock input	3.3V
HPS_CLK2_25	PIN_D20	25 MHz clock input	3.3V

3.5 Peripherals Connected to the FPGA

This section describes the interfaces connected to the FPGA. Users can control or monitor different interfaces with user logic from the FPGA.

3.6.1 User Push-buttons, Switches and LEDs

The board has two push-buttons connected to the FPGA, as shown in **Figure 3-6** Connections between the push-buttons and the Cyclone V SoC FPGA. Schmitt trigger circuit is implemented and act as switch debounce in **Figure 3-7** for the push-buttons connected. The two push-buttons named KEY0 and KEY1 coming out of the Schmitt trigger device are connected directly to the Cyclone V SoC FPGA. The push-button generates a low logic level or high logic level when it is pressed or not, respectively. Since the push-buttons are debounced, they can be used as clock or reset inputs in a circuit.

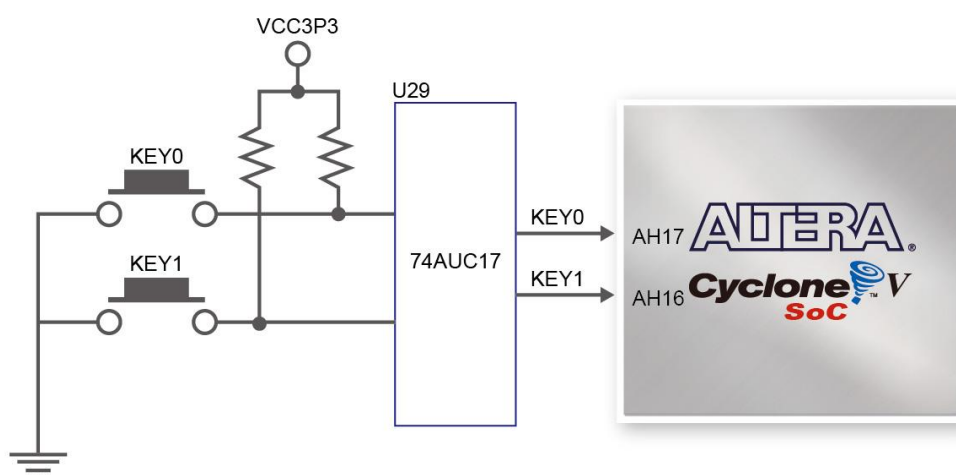


Figure 3-6 Connections between the push-buttons and the Cyclone V SoC FPGA

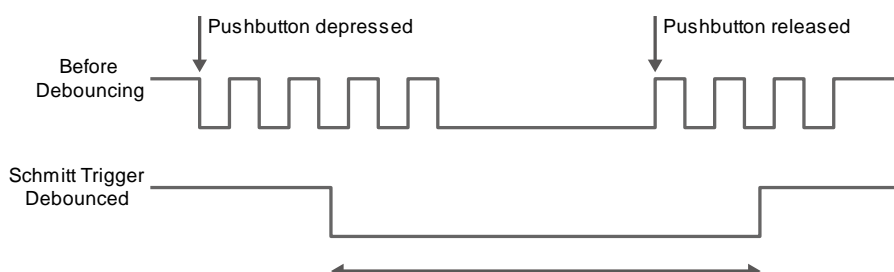


Figure 3-7 Switch debouncing

There are four slide switches connected to the FPGA, as shown in **Figure 3-8**. These switches are not debounced and to be used as level-sensitive data inputs to a circuit. Each switch is connected directly and individually to the FPGA. When the switch is set to the DOWN position (towards the edge of the board), it generates a low logic level to the FPGA. When the switch is set to the UP position, a high logic level is generated to the FPGA.

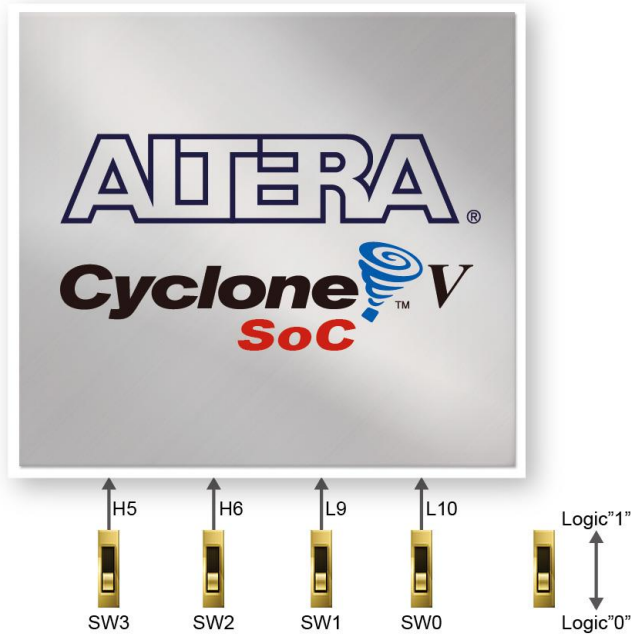


Figure 3-8 Connections between the slide switches and the Cyclone V SoC FPGA

There are also eight user-controllable LEDs connected to the FPGA. Each LED is driven directly and individually by the Cyclone V SoC FPGA; driving its associated pin to a high logic level or low level to turn the LED on or off, respectively. **Figure 3-9** shows the connections between LEDs and Cyclone V SoC FPGA. **Table 3-6**, **Table 3-7** and **Table 3-8** list the pin assignment of user push-buttons, switches, and LEDs.

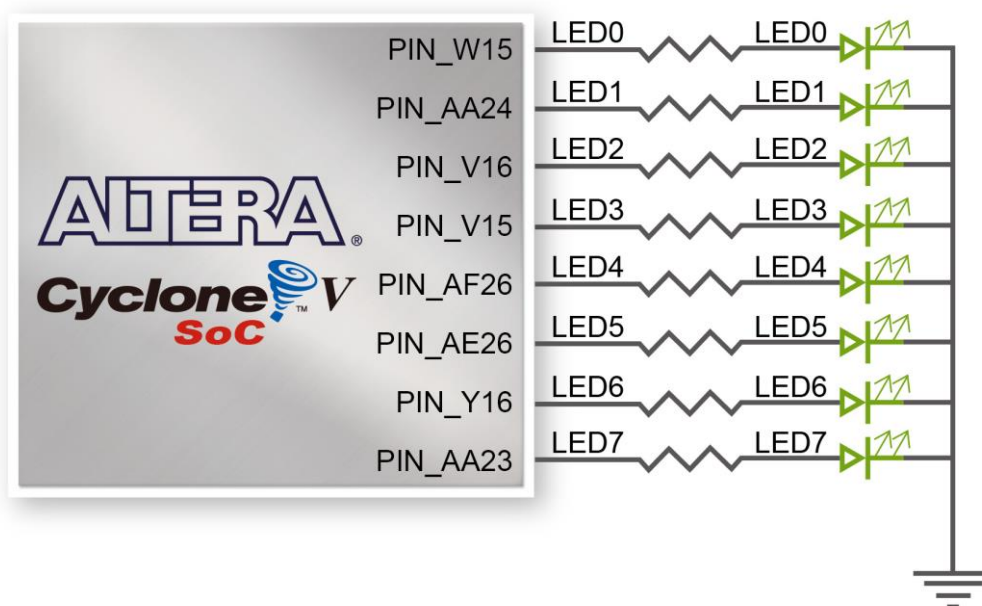


Figure 3-9 Connections between the LEDs and the Cyclone V SoC FPGA

Table 3-6 Pin Assignment of Slide Switches

Signal Name	FPGA Pin No.	Description	I/O Standard
SW[0]	PIN_L10	Slide Switch[0]	3.3V
SW[1]	PIN_L9	Slide Switch[1]	3.3V
SW[2]	PIN_H6	Slide Switch[2]	3.3V
SW[3]	PIN_H5	Slide Switch[3]	3.3V

Table 3-7 Pin Assignment of Push-buttons

Signal Name	FPGA Pin No.	Description	I/O Standard
KEY[0]	PIN_AH17	Push-button[0]	3.3V
KEY[1]	PIN_AH16	Push-button[1]	3.3V

Table 3-8 Pin Assignment of LEDs

Signal Name	FPGA Pin No.	Description	I/O Standard
LED[0]	PIN_W15	LED [0]	3.3V
LED[1]	PIN_AA24	LED [1]	3.3V
LED[2]	PIN_V16	LED [2]	3.3V
LED[3]	PIN_V15	LED [3]	3.3V
LED[4]	PIN_AF26	LED [4]	3.3V
LED[5]	PIN_AE26	LED [5]	3.3V
LED[6]	PIN_Y16	LED [6]	3.3V
LED[7]	PIN_AA23	LED [7]	3.3V

3.6.2 2x20 GPIO Expansion Headers

The board has two 40-pin expansion headers. Each header has 36 user pins connected directly to the Cyclone V SoC FPGA. It also comes with DC +5V (VCC5), DC +3.3V (VCC3P3), and two GND pins. **Figure 3-18** shows the I/O distribution of the GPIO connector. The maximum power consumption allowed for a daughter card connected to one or two GPIO ports is shown in **Table 3-9** and **Table 3-10** shows all the pin assignments of the GPIO connector.

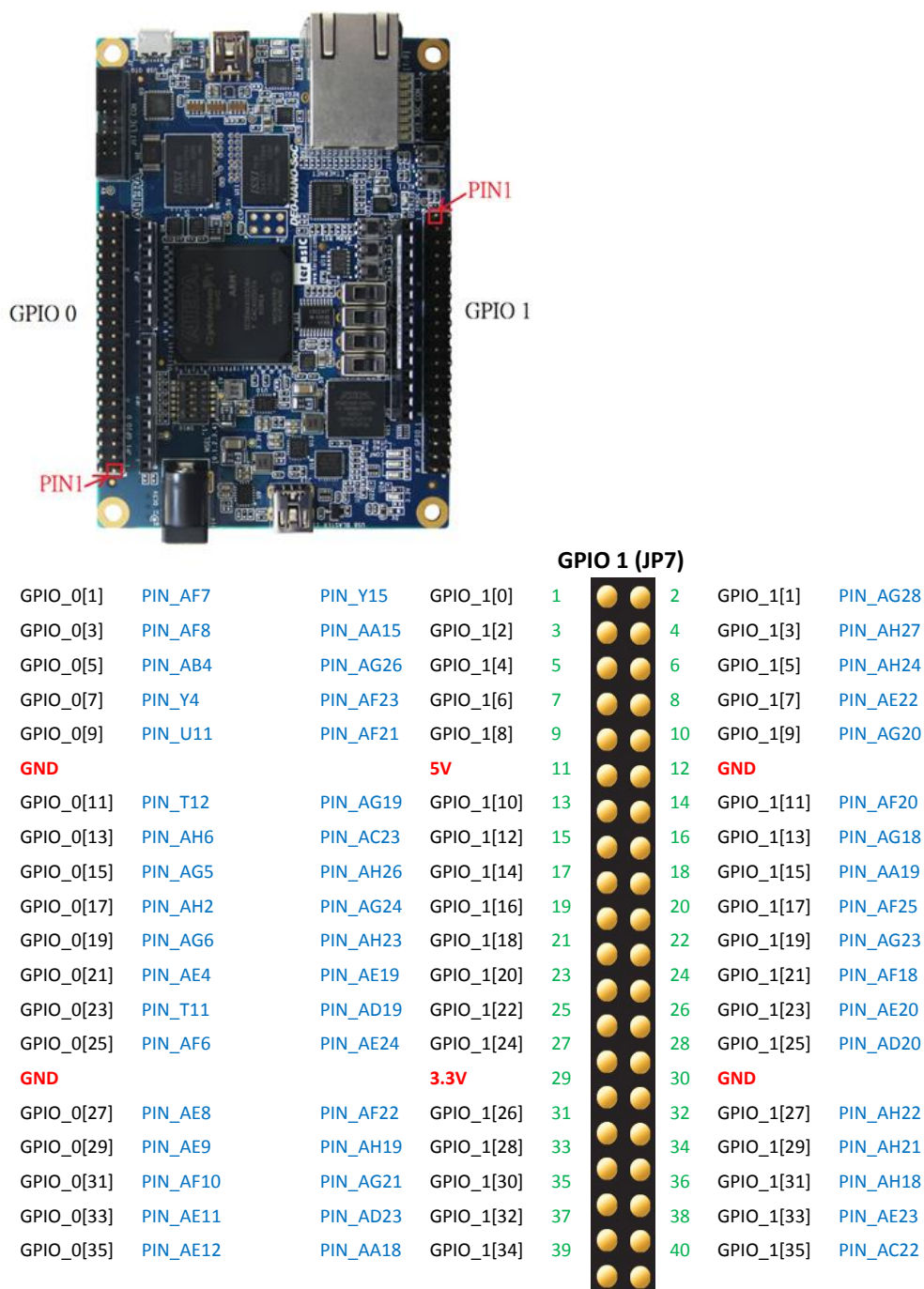


Figure 3-10 GPIO Pin Arrangement

Table 3-9 Voltage and Max. Current Limit of Expansion Header(s)

<i>Supplied Voltage</i>	<i>Max. Current Limit</i>
5V	1A (depend on the power adapter specification.)
3.3V	1.5A

Table 3-10 Pin Assignment of Expansion Headers

<i>Signal Name</i>	<i>FPGA Pin No.</i>	<i>Description</i>	<i>I/O Standard</i>
GPIO_0[0]	PIN_V12	GPIO Connection 0[0]	3.3V
GPIO_0[1]	PIN_AF7	GPIO Connection 0[1]	3.3V
GPIO_0[2]	PIN_W12	GPIO Connection 0[2]	3.3V
GPIO_0[3]	PIN_AF8	GPIO Connection 0[3]	3.3V
GPIO_0[4]	PIN_Y8	GPIO Connection 0[4]	3.3V
GPIO_0[5]	PIN_AB4	GPIO Connection 0[5]	3.3V
GPIO_0[6]	PIN_W8	GPIO Connection 0[6]	3.3V
GPIO_0[7]	PIN_Y4	GPIO Connection 0[7]	3.3V
GPIO_0[8]	PIN_Y5	GPIO Connection 0[8]	3.3V
GPIO_0[9]	PIN_U11	GPIO Connection 0[9]	3.3V
GPIO_0[10]	PIN_T8	GPIO Connection 0[10]	3.3V
GPIO_0[11]	PIN_T12	GPIO Connection 0[11]	3.3V
GPIO_0[12]	PIN_AH5	GPIO Connection 0[12]	3.3V
GPIO_0[13]	PIN_AH6	GPIO Connection 0[13]	3.3V
GPIO_0[14]	PIN_AH4	GPIO Connection 0[14]	3.3V
GPIO_0[15]	PIN_AG5	GPIO Connection 0[15]	3.3V
GPIO_0[16]	PIN_AH3	GPIO Connection 0[16]	3.3V
GPIO_0[17]	PIN_AH2	GPIO Connection 0[17]	3.3V
GPIO_0[18]	PIN_AF4	GPIO Connection 0[18]	3.3V
GPIO_0[19]	PIN_AG6	GPIO Connection 0[19]	3.3V
GPIO_0[20]	PIN_AF5	GPIO Connection 0[20]	3.3V
GPIO_0[21]	PIN_AE4	GPIO Connection 0[21]	3.3V
GPIO_0[22]	PIN_T13	GPIO Connection 0[22]	3.3V
GPIO_0[23]	PIN_T11	GPIO Connection 0[23]	3.3V
GPIO_0[24]	PIN_AE7	GPIO Connection 0[24]	3.3V
GPIO_0[25]	PIN_AF6	GPIO Connection 0[25]	3.3V
GPIO_0[26]	PIN_AF9	GPIO Connection 0[26]	3.3V
GPIO_0[27]	PIN_AE8	GPIO Connection 0[27]	3.3V
GPIO_0[28]	PIN_AD10	GPIO Connection 0[28]	3.3V
GPIO_0[29]	PIN_AE9	GPIO Connection 0[29]	3.3V
GPIO_0[30]	PIN_AD11	GPIO Connection 0[30]	3.3V
GPIO_0[31]	PIN_AF10	GPIO Connection 0[31]	3.3V
GPIO_0[32]	PIN_AD12	GPIO Connection 0[32]	3.3V
GPIO_0[33]	PIN_AE11	GPIO Connection 0[33]	3.3V
GPIO_0[34]	PIN_AF11	GPIO Connection 0[34]	3.3V
GPIO_0[35]	PIN_AE12	GPIO Connection 0[35]	3.3V
GPIO_1[0]	PIN_Y15	GPIO Connection 1[0]	3.3V
GPIO_1[1]	PIN_AG28	GPIO Connection 1[1]	3.3V

GPIO_1[2]	PIN_AA15	GPIO Connection 1[2]	3.3V
GPIO_1[3]	PIN_AH27	GPIO Connection 1[3]	3.3V
GPIO_1[4]	PIN_AG26	GPIO Connection 1[4]	3.3V
GPIO_1[5]	PIN_AH24	GPIO Connection 1[5]	3.3V
GPIO_1[6]	PIN_AF23	GPIO Connection 1[6]	3.3V
GPIO_1[7]	PIN_AE22	GPIO Connection 1[7]	3.3V
GPIO_1[8]	PIN_AF21	GPIO Connection 1[8]	3.3V
GPIO_1[9]	PIN_AG20	GPIO Connection 1[9]	3.3V
GPIO_1[10]	PIN_AG19	GPIO Connection 1[10]	3.3V
GPIO_1[11]	PIN_AF20	GPIO Connection 1[11]	3.3V
GPIO_1[12]	PIN_AC23	GPIO Connection 1[12]	3.3V
GPIO_1[13]	PIN_AG18	GPIO Connection 1[13]	3.3V
GPIO_1[14]	PIN_AH26	GPIO Connection 1[14]	3.3V
GPIO_1[15]	PIN_AA19	GPIO Connection 1[15]	3.3V
GPIO_1[16]	PIN_AG24	GPIO Connection 1[16]	3.3V
GPIO_1[17]	PIN_AF25	GPIO Connection 1[17]	3.3V
GPIO_1[18]	PIN_AH23	GPIO Connection 1[18]	3.3V
GPIO_1[19]	PIN_AG23	GPIO Connection 1[19]	3.3V
GPIO_1[20]	PIN_AE19	GPIO Connection 1[20]	3.3V
GPIO_1[21]	PIN_AF18	GPIO Connection 1[21]	3.3V
GPIO_1[22]	PIN_AD19	GPIO Connection 1[22]	3.3V
GPIO_1[23]	PIN_AE20	GPIO Connection 1[23]	3.3V
GPIO_1[24]	PIN_AE24	GPIO Connection 1[24]	3.3V
GPIO_1[25]	PIN_AD20	GPIO Connection 1[25]	3.3V
GPIO_1[26]	PIN_AF22	GPIO Connection 1[26]	3.3V
GPIO_1[27]	PIN_AH22	GPIO Connection 1[27]	3.3V
GPIO_1[28]	PIN_AH19	GPIO Connection 1[28]	3.3V
GPIO_1[29]	PIN_AH21	GPIO Connection 1[29]	3.3V
GPIO_1[30]	PIN_AG21	GPIO Connection 1[30]	3.3V
GPIO_1[31]	PIN_AH18	GPIO Connection 1[31]	3.3V
GPIO_1[32]	PIN_AD23	GPIO Connection 1[32]	3.3V
GPIO_1[33]	PIN_AE23	GPIO Connection 1[33]	3.3V
GPIO_1[34]	PIN_AA18	GPIO Connection 1[34]	3.3V
GPIO_1[35]	PIN_AC22	GPIO Connection 1[35]	3.3V

3.6.3 Arduino Uno R3 Expansion Header

The board provides Arduino Uno revision 3 compatibility expansion header which comes with four independent headers. The expansion header has 17 user pins (16pins GPIO and 1pin Reset) connected directly to the Cyclone V SoC FPGA. 6-pins Analog input connects to ADC, and also provides DC +9V (VCC9), DC +5V (VCC5), DC +3.3V (VCC3P3 and IOREF), and three GND pins.

Please refer to **Figure 3-11** for detailed pin-out information. The blue font represents the Arduino Uno R3 board pin-out definition.

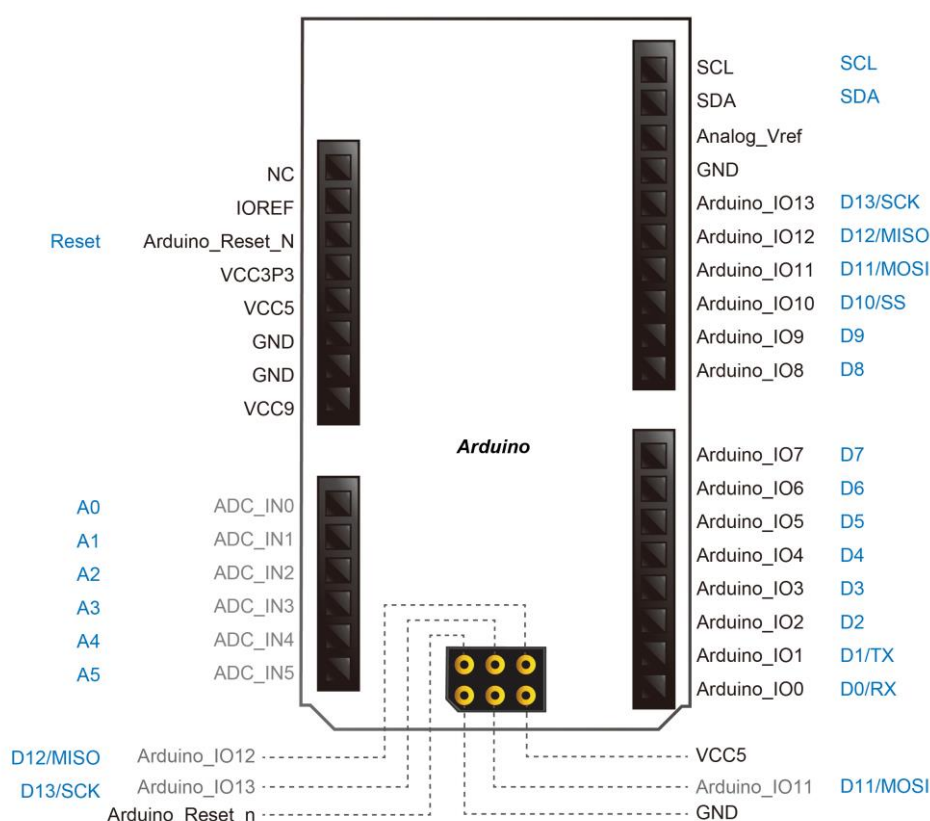


Figure 3-11 lists the all the pin-out signal name of the Arduino Uno connector. The blue font represents the Arduino pin-out definition.

The 16 GPIO pins are provided to the Arduino Header for digital I/O. **Table 3-11** lists the all the pin assignments of the Arduino Uno connector (digital), signal names relative to the Cyclone V SoC FPGA.

Table 3-11 Pin Assignments for Arduino Uno Expansion Header connector

<i>Schematic Signal Name</i>	<i>FPGA Pin No.</i>	<i>Description</i>	<i>Specific features For Arduino</i>	<i>I/O Standard</i>
Arduino_IO0	PIN_AG13	Arduino IO0	RXD	3.3-V
Arduino_IO1	PIN_AF13	Arduino IO1	TXD	3.3-V
Arduino_IO2	PIN_AG10	Arduino IO2		3.3-V
Arduino_IO3	PIN_AG9	Arduino IO3		3.3-V
Arduino_IO4	PIN_U14	Arduino IO4		3.3-V
Arduino_IO5	PIN_U13	Arduino IO5		3.3-V
Arduino_IO6	PIN_AG8	Arduino IO6		3.3-V
Arduino_IO7	PIN_AH8	Arduino IO7		3.3-V
Arduino_IO8	PIN_AF17	Arduino IO8		3.3-V
Arduino_IO9	PIN_AE15	Arduino IO9		3.3-V
Arduino_IO10	PIN_AF15	Arduino IO10	SS	3.3-V
Arduino_IO11	PIN_AG16	Arduino IO11	MOSI	3.3-V
Arduino_IO12	PIN_AH11	Arduino IO12	MISO	3.3-V
Arduino_IO13	PIN_AH12	Arduino IO13	SCK	3.3-V
Arduino_IO14	PIN_AH9	Arduino IO14	SDA	3.3-V
Arduino_IO15	PIN_AG11	Arduino IO15	SCL	3.3-V
Arduino_Reset_n	PIN_AH7	Reset signal, low active.		3.3-V

Besides 16 pins for digital GPIO, there are also 6 analog inputs on the Arduino Uno R3 Expansion Header (ADC_IN0 ~ ADC_IN5). Consequently, we use ADC LTC2308 from Linear Technology on the board for possible future analog-to-digital applications. We will introduce in the next section.

3.6.4 A/D Converter and Analog Input

The Atlas-SoC has an analog-to-digital converter (LTC2308).

The LTC2308 is a low noise, 500ksps, 8-channel, 12-bit ADC with a SPI/MICROWIRE compatible serial interface. This ADC includes an internal reference and a fully differential sample-and-hold circuit to reduce common mode noise. The internal conversion clock allows the external serial output data clock (SCK) to operate at any frequency up to 40MHz.

It can be configured to accept eight input signals at inputs ADC_IN0 through ADC_IN7. These eight input signals are connected to a 2x5 header, as shown in [Figure 3-12](#).

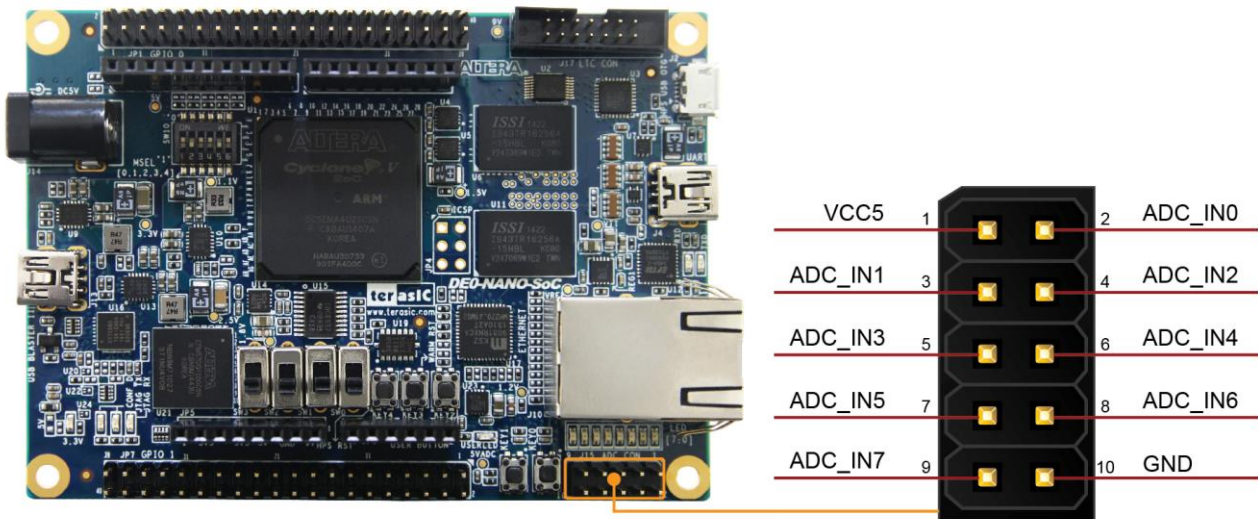


Figure 3-12 Signals of the 2x5 Header

These Analog inputs are shared with the Arduino's analog input pin (ADC_IN0 ~ ADC_IN5),

Figure 3-13 shows the connections between the FPGA, 2x5 header, Arduino Analog input, and the A/D converter.

More information about the A/D converter chip can be found on manufacturer's website (<http://www.linear.com/product/LTC2308>).

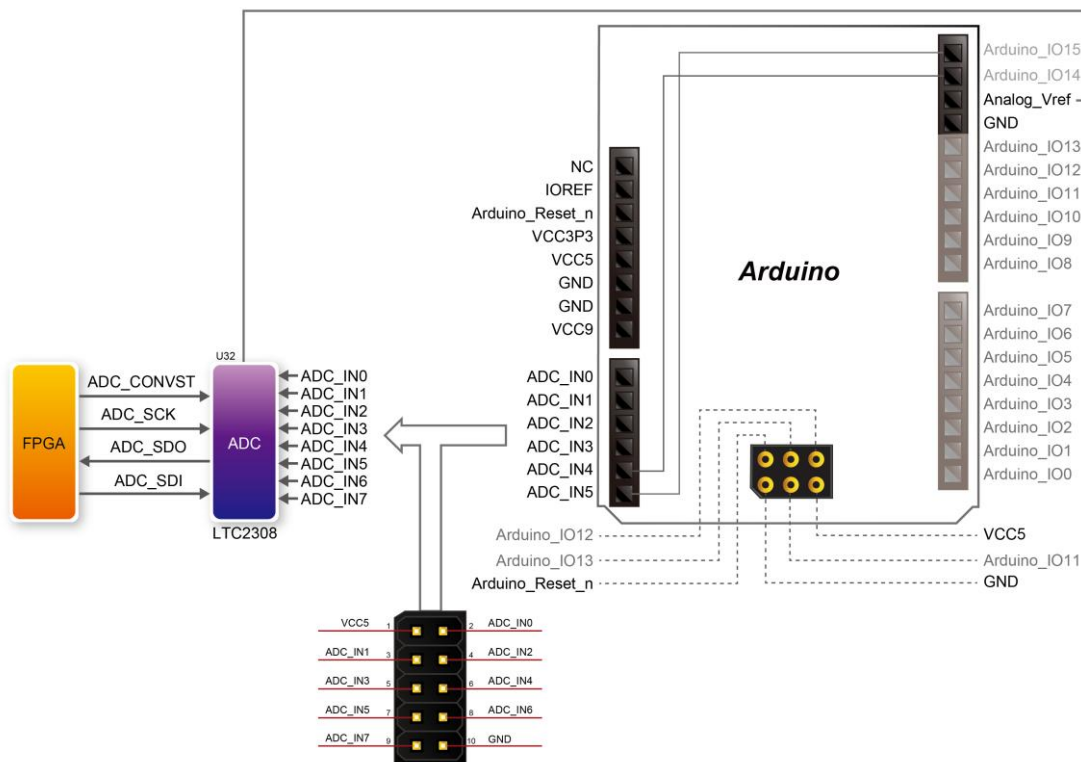


Figure 3-13 Connections between the FPGA, 2x5 header, and the A/D converter

Table 3-12 Pin Assignment of ADC

<i>Signal Name</i>	<i>FPGA Pin No.</i>	<i>Description</i>	<i>I/O Standard</i>
ADC_CONVST	PIN_U9	Conversion Start	3.3V
ADC_SCK	PIN_V10	Serial Data Clock	3.3V
ADC_SDI	PIN_AC4	Serial Data Input (FPGA to ADC)	3.3V
ADC_SDO	PIN_AD4	Serial Data Out (ADC to FPGA)	3.3V

3.6 Peripherals Connected to Hard Processor System (HPS)

This section introduces the interfaces connected to the HPS section of the Cyclone V SoC FPGA. Users can access these interfaces via the HPS processor.

3.7.1 User Push-buttons and LEDs

Similar to the FPGA, the HPS also has its set of switches, buttons, LEDs, and other interfaces connected exclusively. Users can control these interfaces to monitor the status of HPS.

Table 3-13 gives the pin assignment of all the LEDs, switches, and push-buttons.

Table 3-13 Pin Assignment of LEDs, Switches and Push-buttons

<i>Signal Name</i>	<i>FPGA Pin No.</i>	<i>HPS GPIO</i>	<i>Register/bit</i>	<i>Function</i>
HPS_KEY	PIN_J18	GPIO54	GPIO1[25]	I/O
HPS_LED	PIN_A20	GPIO53	GPIO1[24]	I/O

3.7.2 Gigabit Ethernet

The board supports Gigabit Ethernet transfer by an external Micrel KSZ9031RN PHY chip and HPS Ethernet MAC function. The KSZ9031RN chip with integrated 10/100/1000 Mbps Gigabit Ethernet transceiver also supports RGMII MAC interface. **Figure 3-14** shows the connections between the HPS, Gigabit Ethernet PHY, and RJ-45 connector.

The pin assignment associated to Gigabit Ethernet interface is listed in **Table 3-14**. More information about the KSZ9031RN PHY chip and its datasheet, as well as the application notes, which are available on the manufacturer's website (<http://www.micrel.com/index.php/products/lan-solutions/phys/article/2-ksz9031rn.html>).

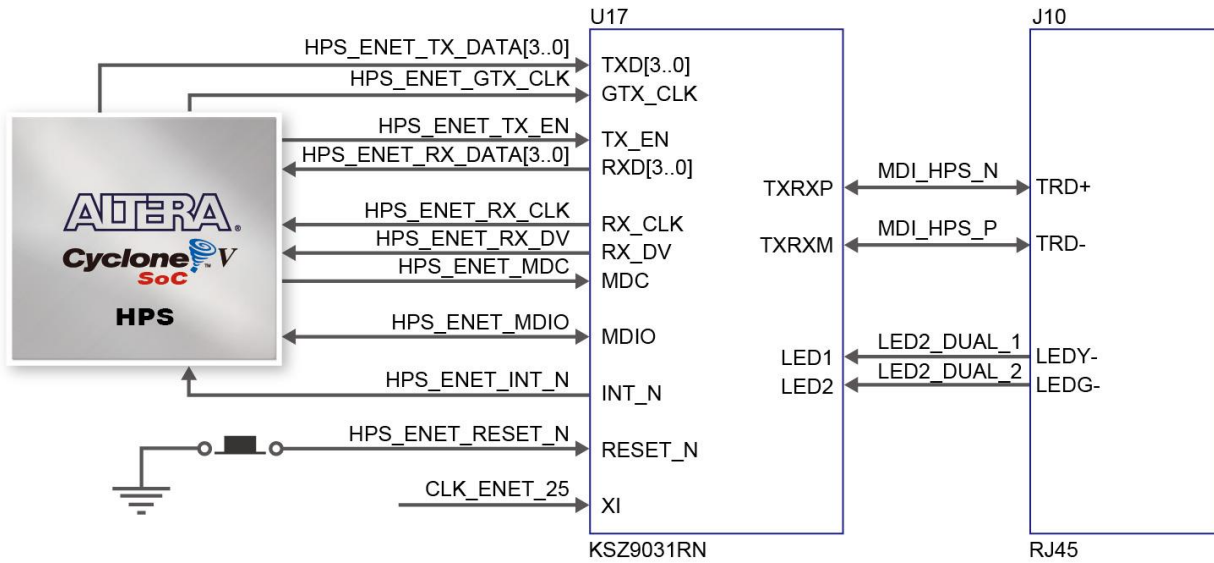


Figure 3-14 Connections between the HPS and Gigabit Ethernet

Table 3-14 Pin Assignment of Gigabit Ethernet PHY

Signal Name	FPGA Pin No.	Description	I/O Standard
HPS_ENET_TX_EN	PIN_A12	GMII and MII transmit enable	3.3V
HPS_ENET_TX_DATA[0]	PIN_A16	MIl transmit data[0]	3.3V
HPS_ENET_TX_DATA[1]	PIN_J14	MIl transmit data[1]	3.3V
HPS_ENET_TX_DATA[2]	PIN_A15	MIl transmit data[2]	3.3V
HPS_ENET_TX_DATA[3]	PIN_D17	MIl transmit data[3]	3.3V
HPS_ENET_RX_DV	PIN_J13	GMII and MII receive data valid	3.3V
HPS_ENET_RX_DATA[0]	PIN_A14	GMII and MII receive data[0]	3.3V
HPS_ENET_RX_DATA[1]	PIN_A11	GMII and MII receive data[1]	3.3V
HPS_ENET_RX_DATA[2]	PIN_C15	GMII and MII receive data[2]	3.3V
HPS_ENET_RX_DATA[3]	PIN_A9	GMII and MII receive data[3]	3.3V
HPS_ENET_RX_CLK	PIN_J12	GMII and MII receive clock	3.3V
HPS_ENET_RESET_N	PIN_B14	Hardware Reset Signal	3.3V
HPS_ENET_MDIO	PIN_E16	Management Data	3.3V
HPS_ENET_MDC	PIN_A13	Management Data Clock Reference	3.3V
HPS_ENET_INT_N	PIN_B14	Interrupt Open Drain Output	3.3V
HPS_ENET_GTX_CLK	PIN_J15	GMII Transmit Clock	3.3V

There are two LEDs, green LED (LEDG) and yellow LED (LEDY), which represent the status of Ethernet PHY (KSZ9031RN). The LED control signals are connected to the LEDs on the RJ45 connector. The state and definition of LEDG and LEDY are listed in [Table 3-15](#). For instance, the connection from board to Gigabit Ethernet is established once the LEDG lights on.

Table 3-15 State and Definition of LED Mode Pins

LED (State)		LED (Definition)		Link /Activity
LEDG	LEDY	LEDG	LEDY	
H	H	OFF	OFF	Link off
L	H	ON	OFF	1000 Link / No Activity
Toggle	H	Blinking	OFF	1000 Link / Activity (RX, TX)
H	L	OFF	ON	100 Link / No Activity
H	Toggle	OFF	Blinking	100 Link / Activity (RX, TX)
L	L	ON	ON	10 Link/ No Activity
Toggle	Toggle	Blinking	Blinking	10 Link / Activity (RX, TX)

3.7.3 UART

The board has one UART interface connected for communication with the HPS. This interface doesn't support HW flow control signals. The physical interface is implemented by UART-USB onboard bridge from a FT232R chip to the host with an USB Mini-B connector. More information about the chip is available on the manufacturer's website (<http://www.ftdichip.com/Products/ICs/FT232R.htm>). **Figure 3-15** shows the connections between the HPS, FT232R chip, and the USB Mini-B connector. **Table 3-16** lists the pin assignment of UART interface connected to the HPS.

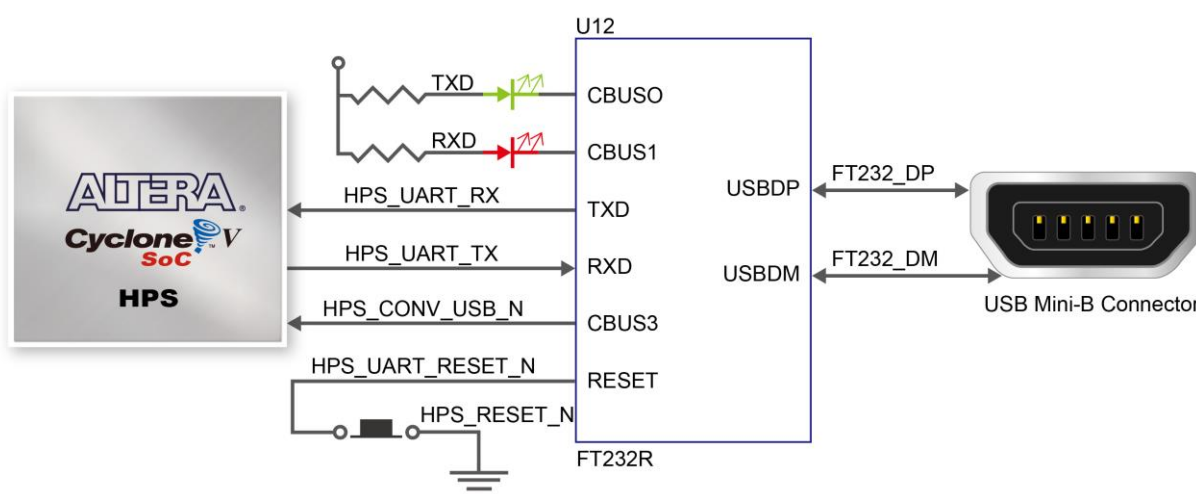


Figure 3-15 Connections between the HPS and FT232R Chip

Table 3-16 Pin Assignment of UART Interface

Signal Name	FPGA Pin No.	Description	I/O Standard
HPS_UART_RX	PIN_A22	HPS UART Receiver	3.3V
HPS_UART_TX	PIN_B21	HPS UART Transmitter	3.3V
HPS_CONV_USB_N	PIN_C6	Reserve	3.3V

3.7.4 DDR3 Memory

The DDR3 devices connected to the HPS are the exact same model as the ones connected to the FPGA. The capacity is 1GB and the data bandwidth is in 32-bit, comprised of two x16 devices with a single address/command bus. The signals are connected to the dedicated Hard Memory Controller for HPS I/O banks and the target speed is 400 MHz. **Table 3-17** lists the pin assignment of DDR3 and its description with I/O standard.

Table 3-17 Pin Assignment of DDR3 Memory

<i>Signal Name</i>	<i>FPGA Pin No.</i>	<i>Description</i>	<i>I/O Standard</i>
HPS_DDR3_A[0]	PIN_C28	HPS DDR3 Address[0]	SSTL-15 Class I
HPS_DDR3_A[1]	PIN_B28	HPS DDR3 Address[1]	SSTL-15 Class I
HPS_DDR3_A[2]	PIN_E26	HPS DDR3 Address[2]	SSTL-15 Class I
HPS_DDR3_A[3]	PIN_D26	HPS DDR3 Address[3]	SSTL-15 Class I
HPS_DDR3_A[4]	PIN_J21	HPS DDR3 Address[4]	SSTL-15 Class I
HPS_DDR3_A[5]	PIN_J20	HPS DDR3 Address[5]	SSTL-15 Class I
HPS_DDR3_A[6]	PIN_C26	HPS DDR3 Address[6]	SSTL-15 Class I
HPS_DDR3_A[7]	PIN_B26	HPS DDR3 Address[7]	SSTL-15 Class I
HPS_DDR3_A[8]	PIN_F26	HPS DDR3 Address[8]	SSTL-15 Class I
HPS_DDR3_A[9]	PIN_F25	HPS DDR3 Address[9]	SSTL-15 Class I
HPS_DDR3_A[10]	PIN_A24	HPS DDR3 Address[10]	SSTL-15 Class I
HPS_DDR3_A[11]	PIN_B24	HPS DDR3 Address[11]	SSTL-15 Class I
HPS_DDR3_A[12]	PIN_D24	HPS DDR3 Address[12]	SSTL-15 Class I
HPS_DDR3_A[13]	PIN_C24	HPS DDR3 Address[13]	SSTL-15 Class I
HPS_DDR3_A[14]	PIN_G23	HPS DDR3 Address[14]	SSTL-15 Class I
HPS_DDR3_BA[0]	PIN_A27	HPS DDR3 Bank Address[0]	SSTL-15 Class I
HPS_DDR3_BA[1]	PIN_H25	HPS DDR3 Bank Address[1]	SSTL-15 Class I
HPS_DDR3_BA[2]	PIN_G25	HPS DDR3 Bank Address[2]	SSTL-15 Class I
HPS_DDR3_CAS_n	PIN_A26	DDR3 Column Address Strobe	SSTL-15 Class I
HPS_DDR3_CKE	PIN_L28	HPS DDR3 Clock Enable	SSTL-15 Class I
HPS_DDR3_CK_n	PIN_N20	HPS DDR3 Clock	Differential 1.5-V SSTL Class I
HPS_DDR3_CK_p	PIN_N21	HPS DDR3 Clock p	Differential 1.5-V SSTL Class I
HPS_DDR3_CS_n	PIN_L21	HPS DDR3 Chip Select	SSTL-15 Class I
HPS_DDR3_DM[0]	PIN_G28	HPS DDR3 Data Mask[0]	SSTL-15 Class I
HPS_DDR3_DM[1]	PIN_P28	HPS DDR3 Data Mask[1]	SSTL-15 Class I
HPS_DDR3_DM[2]	PIN_W28	HPS DDR3 Data Mask[2]	SSTL-15 Class I
HPS_DDR3_DM[3]	PIN_AB28	HPS DDR3 Data Mask[3]	SSTL-15 Class I
HPS_DDR3_DQ[0]	PIN_J25	HPS DDR3 Data[0]	SSTL-15 Class I
HPS_DDR3_DQ[1]	PIN_J24	HPS DDR3 Data[1]	SSTL-15 Class I
HPS_DDR3_DQ[2]	PIN_E28	HPS DDR3 Data[2]	SSTL-15 Class I
HPS_DDR3_DQ[3]	PIN_D27	HPS DDR3 Data[3]	SSTL-15 Class I
HPS_DDR3_DQ[4]	PIN_J26	HPS DDR3 Data[4]	SSTL-15 Class I
HPS_DDR3_DQ[5]	PIN_K26	HPS DDR3 Data[5]	SSTL-15 Class I

HPS_DDR3_DQ[6]	PIN_G27	HPS DDR3 Data[6]	SSTL-15 Class I
HPS_DDR3_DQ[7]	PIN_F28	HPS DDR3 Data[7]	SSTL-15 Class I
HPS_DDR3_DQ[8]	PIN_K25	HPS DDR3 Data[8]	SSTL-15 Class I
HPS_DDR3_DQ[9]	PIN_L25	HPS DDR3 Data[9]	SSTL-15 Class I
HPS_DDR3_DQ[10]	PIN_J27	HPS DDR3 Data[10]	SSTL-15 Class I
HPS_DDR3_DQ[11]	PIN_J28	HPS DDR3 Data[11]	SSTL-15 Class I
HPS_DDR3_DQ[12]	PIN_M27	HPS DDR3 Data[12]	SSTL-15 Class I
HPS_DDR3_DQ[13]	PIN_M26	HPS DDR3 Data[13]	SSTL-15 Class I
HPS_DDR3_DQ[14]	PIN_M28	HPS DDR3 Data[14]	SSTL-15 Class I
HPS_DDR3_DQ[15]	PIN_N28	HPS DDR3 Data[15]	SSTL-15 Class I
HPS_DDR3_DQ[16]	PIN_N24	HPS DDR3 Data[16]	SSTL-15 Class I
HPS_DDR3_DQ[17]	PIN_N25	HPS DDR3 Data[17]	SSTL-15 Class I
HPS_DDR3_DQ[18]	PIN_T28	HPS DDR3 Data[18]	SSTL-15 Class I
HPS_DDR3_DQ[19]	PIN_U28	HPS DDR3 Data[19]	SSTL-15 Class I
HPS_DDR3_DQ[20]	PIN_N26	HPS DDR3 Data[20]	SSTL-15 Class I
HPS_DDR3_DQ[21]	PIN_N27	HPS DDR3 Data[21]	SSTL-15 Class I
HPS_DDR3_DQ[22]	PIN_R27	HPS DDR3 Data[22]	SSTL-15 Class I
HPS_DDR3_DQ[23]	PIN_V27	HPS DDR3 Data[23]	SSTL-15 Class I
HPS_DDR3_DQ[24]	PIN_R26	HPS DDR3 Data[24]	SSTL-15 Class I
HPS_DDR3_DQ[25]	PIN_R25	HPS DDR3 Data[25]	SSTL-15 Class I
HPS_DDR3_DQ[26]	PIN_AA28	HPS DDR3 Data[26]	SSTL-15 Class I
HPS_DDR3_DQ[27]	PIN_W26	HPS DDR3 Data[27]	SSTL-15 Class I
HPS_DDR3_DQ[28]	PIN_R24	HPS DDR3 Data[28]	SSTL-15 Class I
HPS_DDR3_DQ[29]	PIN_T24	HPS DDR3 Data[29]	SSTL-15 Class I
HPS_DDR3_DQ[30]	PIN_Y27	HPS DDR3 Data[30]	SSTL-15 Class I
HPS_DDR3_DQ[31]	PIN_AA27	HPS DDR3 Data[31]	SSTL-15 Class I
HPS_DDR3_DQS_n[0]	PIN_R16	HPS DDR3 Data Strobe n[0]	Differential 1.5-V SSTL Class I
HPS_DDR3_DQS_n[1]	PIN_R18	HPS DDR3 Data Strobe n[1]	Differential 1.5-V SSTL Class I
HPS_DDR3_DQS_n[2]	PIN_T18	HPS DDR3 Data Strobe n[2]	Differential 1.5-V SSTL Class I
HPS_DDR3_DQS_n[3]	PIN_T20	HPS DDR3 Data Strobe n[3]	Differential 1.5-V SSTL Class I
HPS_DDR3_DQS_p[0]	PIN_R17	HPS DDR3 Data Strobe p[0]	Differential 1.5-V SSTL Class I
HPS_DDR3_DQS_p[1]	PIN_R19	HPS DDR3 Data Strobe p[1]	Differential 1.5-V SSTL Class I
HPS_DDR3_DQS_p[2]	PIN_T19	HPS DDR3 Data Strobe p[2]	Differential 1.5-V SSTL Class I
HPS_DDR3_DQS_p[3]	PIN_U19	HPS DDR3 Data Strobe p[3]	Differential 1.5-V SSTL Class I
HPS_DDR3_ODT	PIN_D28	HPS DDR3 On-die Termination	SSTL-15 Class I
HPS_DDR3_RAS_n	PIN_A25	DDR3 Row Address Strobe	SSTL-15 Class I
HPS_DDR3_RESET_n	PIN_V28	HPS DDR3 Reset	SSTL-15 Class I
HPS_DDR3_WE_n	PIN_E25	HPS DDR3 Write Enable	SSTL-15 Class I
HPS_DDR3_RZQ	PIN_D25	External reference ball for output drive calibration	1.5 V

3.7.5 Micro SD Card Socket

The board supports Micro SD card interface with x4 data lines. It serves not only an external storage for the HPS, but also an alternative boot option for DE0-Nano0-SoC board. **Figure 3-16** shows signals connected between the HPS and Micro SD card socket.

Table 3-18 lists the pin assignment of Micro SD card socket to the HPS.

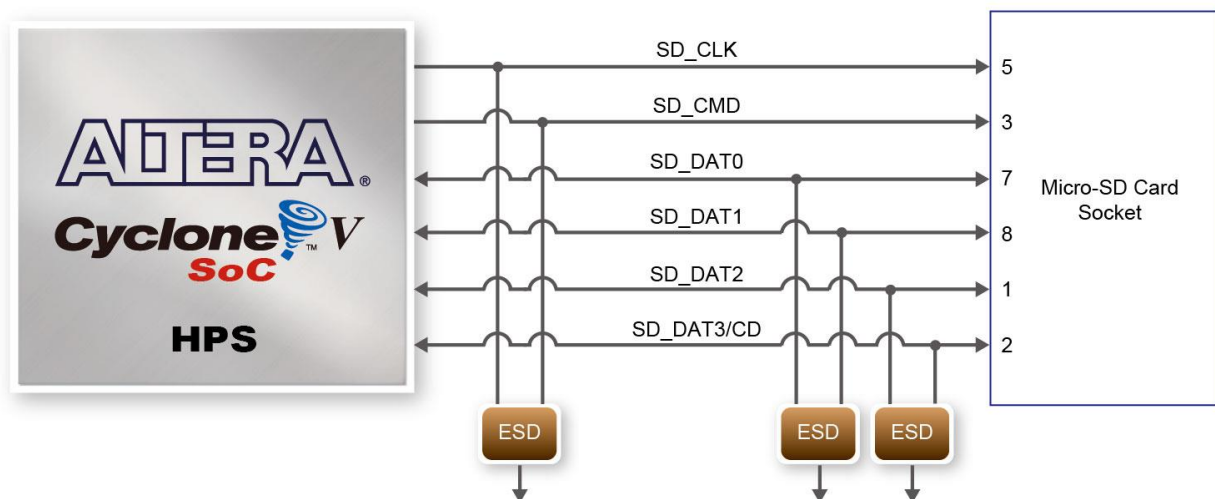


Figure 3-16 Connections between the FPGA and SD card socket

Table 3-18 Pin Assignment of Micro SD Card Socket

Signal Name	FPGA Pin No.	Description	I/O Standard
HPS_SD_CLK	PIN_B8	HPS SD Clock	3.3V
HPS_SD_CMD	PIN_D14	HPS SD Command Line	3.3V
HPS_SD_DATA[0]	PIN_C13	HPS SD Data[0]	3.3V
HPS_SD_DATA[1]	PIN_B6	HPS SD Data[1]	3.3V
HPS_SD_DATA[2]	PIN_B11	HPS SD Data[2]	3.3V
HPS_SD_DATA[3]	PIN_B9	HPS SD Data[3]	3.3V

3.7.6 USB 2.0 OTG PHY

The board provides USB interfaces using the SMSC USB3300 controller. A SMSC USB3300 device in a 32-pin QFN package device is used to interface to a single Type AB Micro-USB connector. This device supports UTMI+ Low Pin Interface (ULPI) to communicate to USB 2.0 controller in HPS. As defined by OTG mode, the PHY can operate in Host or Device modes. When operating in Host mode, the interface will supply the power to the device through the Micro-USB interface. **Figure 3-17** shows the connections of USB PTG PHY to the HPS. **Table 3-19** lists the pin assignment of USB OTG PHY to the HPS.

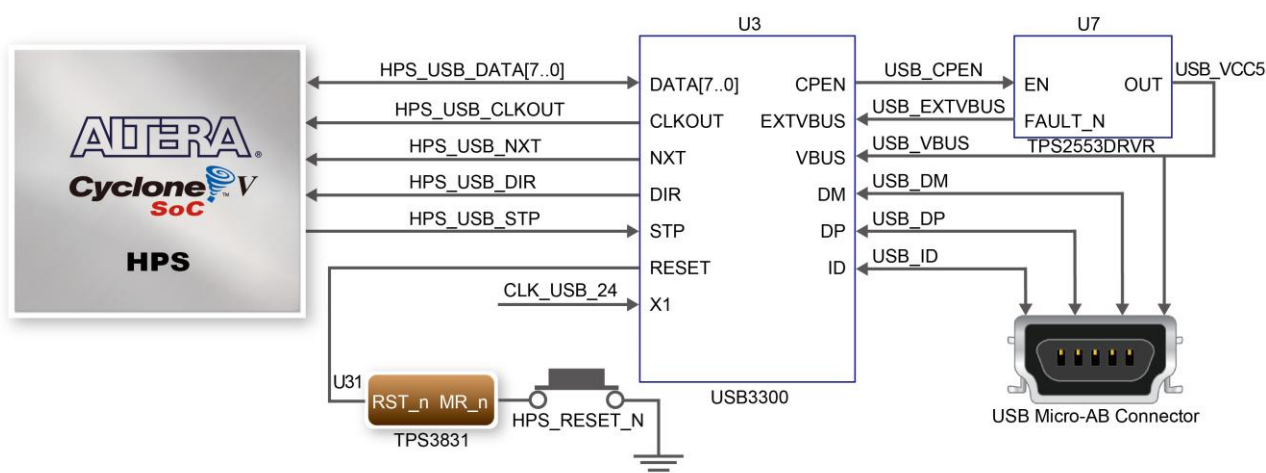


Figure 3-17 Connections between the HPS and USB OTG PHY

Table 3-19 Pin Assignment of USB OTG PHY

Signal Name	FPGA Pin No.	Description	I/O Standard
HPS_USB_CLKOUT	PIN_G4	60MHz Reference Clock Output	3.3V
HPS_USB_DATA[0]	PIN_C10	HPS USB_DATA[0]	3.3V
HPS_USB_DATA[1]	PIN_F5	HPS USB_DATA[1]	3.3V
HPS_USB_DATA[2]	PIN_C9	HPS USB_DATA[2]	3.3V
HPS_USB_DATA[3]	PIN_C4	HPS USB_DATA[3]	3.3V
HPS_USB_DATA[4]	PIN_C8	HPS USB_DATA[4]	3.3V
HPS_USB_DATA[5]	PIN_D4	HPS USB_DATA[5]	3.3V
HPS_USB_DATA[6]	PIN_C7	HPS USB_DATA[6]	3.3V
HPS_USB_DATA[7]	PIN_F4	HPS USB_DATA[7]	3.3V
HPS_USB_DIR	PIN_E5	Direction of the Data Bus	3.3V
HPS_USB_NXT	PIN_D5	Throttle the Data	3.3V
HPS_USB_RESET	PIN_H12	HPS USB PHY Reset	3.3V
HPS_USB_STP	PIN_C5	Stop Data Stream on the Bus	3.3V

3.7.7 G-sensor

The board comes with a digital accelerometer sensor module (ADXL345), commonly known as G-sensor. This G-sensor is a small, thin, ultralow power assumption 3-axis accelerometer with high-resolution measurement. Digitalized output is formatted as 16-bit in two's complement and can be accessed through I2C interface. The I2C address of G-sensor is 0xA6/0xA7. More information about this chip can be found in its datasheet, which is available on manufacturer's website (<http://www.analog.com/en/products/mems/mems-accelerometers/adxl345.html>). **Figure 3-18** shows the connections between the HPS and G-sensor. **Table 3-20** lists the pin assignment of G-sensor to the HPS.

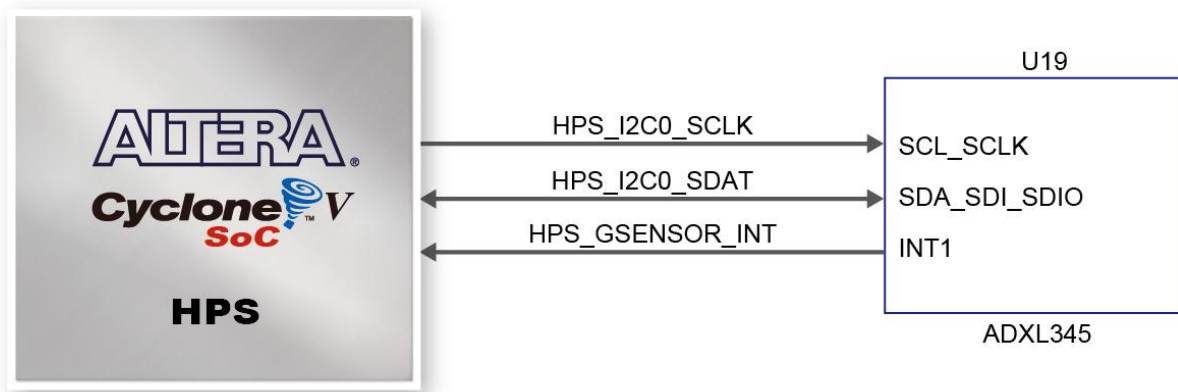


Figure 3-18 Connections between Cyclone V SoC FPGA and G-Sensor

Table 3-20 Pin Assignment of G-sensor

Signal Name	FPGA Pin No.	Description	I/O Standard
HPS_GSENSOR_INT	PIN_A17	HPS GSENSOR Interrupt Output	3.3V
HPS_I2C0_SCLK	PIN_C18	HPS I2C0 Clock	3.3V
HPS_I2C0_SDAT	PIN_A19	HPS I2C0 Data	3.3V

3.7.8 LTC Connector

The board has a 14-pin header, which is originally used to communicate with various daughter cards from Linear Technology. It is connected to the SPI Master and I2C ports of HPS. The communication with these two protocols is bi-directional. The 14-pin header can also be used for GPIO, SPI, or I2C based communication with the HPS. Connections between the HPS and LTC connector are shown in **Figure 3-19**, and the pin assignment of LTC connector is listed in **Table 3-21**.

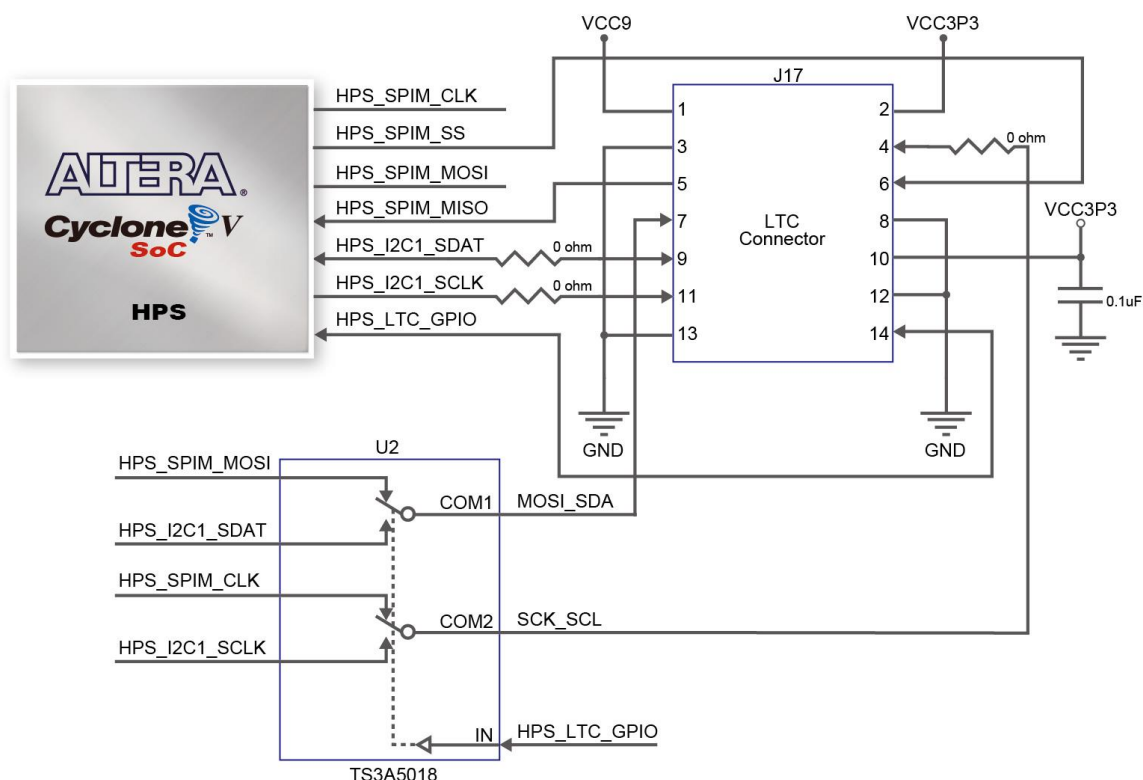


Figure 3-19 Connections between the HPS and LTC connector

Table 3-21 Pin Assignment of LTC Connector

Signal Name	FPGA Pin No.	Description	I/O Standard
HPS_LTC_GPIO	PIN_H13	HPS LTC GPIO	3.3V
HPS_I2C1_SCLK	PIN_B21	HPS I2C1 Clock	3.3V
HPS_I2C1_SDAT	PIN_A21	HPS I2C1 Data	3.3V
HPS_SPIM_CLK	PIN_C19	SPI Clock	3.3V
HPS_SPIM_MISO	PIN_B19	SPI Master Input/Slave Output	3.3V
HPS_SPIM_MOSI	PIN_B16	SPI Master Output /Slave Input	3.3V
HPS_SPIM_SS	PIN_C16	SPI Slave Select	3.3V

4.1 Revision History

Version	Change Log
V1.0	Initial Version (Preliminary)
V1.1	Minor corrections: fixing Table 3-2.
V1.2	Add GPIO pin Arrangement (Figure 3-18)

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